

RDR Cost Estimating Instructions & Standards

http://www-ilcdcb.fnal.gov/RDR_Cost_Estimating_Instructions_23may06.pdf

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0. Acknowledgements: The Design Cost Board was primarily responsible for preparing these instructions. Many of these sections are adaptations of the notes prepared for the earlier NLC and ULCTOS cost estimates by John Cornuelle and Ray Larsen. The early May 2006 draft was also reviewed by Jean-Luc Baldy, Ryuhei Suguhara, and Tom Peterson who provided many suggestions to improve the readability and understandability of this document. Many thanks to them all!

1. Introduction and Cost Consciousness

The design selected for cost estimating should represent the optimal balance (best value) between technical performance, reliability, acquisition cost, and operating cost (over a 10 year minimum operating lifetime). The cost of the best value design should be as low as is practicable, feasible, and reasonable, and consistent with performance and reliability.

These instructions provide the next level of detail, after the more general instructions, which can be found at

http://www-ilcdecb.fnal.gov/RDR_costing_guidelines.pdf

for preparing the cost estimates. The estimates for the ILC construction project are requested to be sent to the Cost Engineers (Tetsuo Shidara, Wilhelm Bialowons, and Peter Garbincius) by June 25, 2006. By September 15, 2006, cost estimates will also be needed for the non-construction aspects defined below.

2. What's Included in the ILC Construction Cost Estimate?

For the estimate required for Vancouver in late July, 2006 we concentrate only on the cost estimate for the construction project including accelerator and detectors, tooling-up industry for production of ILC quantities of components, and the (contract) final engineering designs. Although we are initially only considering the cost of the 500 GeV configuration, we must include those costs that should be included from the beginning for the upgrade to 1 TeV that would be difficult to provide later. These include providing adequate tunnel space for the 1 TeV Beam Delivery System, beam dumps sized for 1 TeV operations, and surface land and underground easements for 1 TeV. The construction project does not include R&D, proof-of-principle (system) test, commissioning, operations, or decommissioning. Construction project costs are counted, beginning only at t_0 , when funding authorization is obtained, and not before. Estimates for these non-construction categories, and some others that may or may not be included in the construction cost estimate, will be required after Vancouver. For more details see

http://www-ilcdecb.fnal.gov/RDR/ilc_construction_cost_estimate_6may06.pdf

3. Definitions of Responsibilities:

3.a. Design Cost Board (DCB) is responsible for the RDR and cost estimate. The chairman of the DCB reports to the ILC Executive Committee and the GDE Director. DCB responsibilities include:

- Create and maintain the Master WBS (Work Breakdown Structure)
- Creates and maintains the master schedule
- Defines cost methodology used by Area and Technical system leaders
- Integrates cost data provided by Area and Technical system leaders into master cost estimate and schedule
- Works with Area and Technical System leaders to assure a uniform quality of the cost estimation
- Provides estimates for the overall project risk budget

3.b. Area Systems group leaders are responsible for specifying the major machine areas: Electron Source, Positron Source, Damping Rings, Rings-to-Main-Linac, Main Linac, Beam Delivery System:

- Area System group leaders must establish the overall Work Breakdown Structure (WBS) for their Area Systems. Technical System and Global System leaders will provide the next levels of details and cost estimates for this WBS to the Area System leaders.
- Technical Systems leaders are responsible to the Area System leaders
- Area System leaders are responsible for optimal balance (best value) between technical performance, reliability, acquisition cost, and operating cost
- Area System leaders collectively **establish the interfaces & boundaries** (physical, electrical, beam parameters, etc) for the basis of cost estimates.
- Area System leaders provide layouts and drawings, component counts, component requirements, and overall system requirements to Technical System leaders.

3.c. Technical Systems group leaders responsibilities include:

- Design, cost analysis and scheduling of ILC technical systems
- Optimization and standardization of system designs across the machine
- Develop Definitions, Descriptions, Specifications
- Establishing the WBS structure for their sub-systems
- Establishing a WBS dictionary which describes each WBS task, see http://www-ilcddb.fnal.gov/RDR/WBS_Dictionary_Example.pdf
- Choose model for basis of estimate http://www-ilcddb.fnal.gov/RDR/Basis_of_Estimate.pdf
- Perform scaling, parametric or bottoms up estimates
- Follow *standard checklist* to estimate activities, materials, labor, equipment for task. Here is an example: http://www-ilcddb.fnal.gov/RDR/NLC_X-Band_Estimate_042406.xls
- Quote cost estimate to 50% confidence level (50% chance cost will be above, 50% chance cost will be below quoted estimate).
- Perform technical reliability and risk analysis
- Produce top level cost summaries in Excel (or SLAC WBS Tool) format
- Evaluate factors for cost risk analysis
- Transfer this cost information to Design Cost Board (DCB)

3.d. Global Systems groups provide both complete sub-systems themselves (e.g. conventional facilities, cryogenics, installation, and the common control system), and provide overall guidance, specifications, compatibility, uniformity, and coherence across the Area Systems and Technical Systems. Thus, the Global System leaders have responsibilities that are a combination of those for the Area Systems and Technical Systems described above and should review and adapt those that apply to their particular system as appropriate.

4. Work Breakdown Structure (WBS)

4.a. Definition and Content. The cost estimates should be provided in the form of a Work Breakdown Structure (WBS). WBS is a system that allows an estimate of total project construction and labor costs by summing the costs of all tasks or items to be purchased (WBS elements) to yield an estimate of the total project cost. Typically a WBS element will contain both Materials and Services (M&S) and internal (collaborating institutional) labor. In order for each region to properly consider internal institutional labor within their own funding systems, this internal institutional labor will be compiled in terms of person-hours, and not in terms of personnel costs. M&S is typically something that one purchases. Labor is people being paid to do a job. Note that the labor costs of industrial firms to which contracts to deliver a product are placed are de facto included in the M&S cost of the item to be delivered and should not be included or double counted. There is at least one area of ambiguity: there are certain tasks such as installation and alignment that could be accomplished either by internal institutional labor or under contract to a commercial company. Unless a cost estimate is available for a commercial contract for these services, an estimate of the person-hours for internal institutional labor should be provided. For consistency and completeness, if a component will be manufactured internally by a collaborating institution or Laboratory using its own staff, the estimate of the person-hours of that institutional labor also must be included.

A good cost estimate requires that those making the estimate do not “miss” elements that should be there. Please use this checklist to insure that all the WBS elements that should be in the estimate are really there for your subsystem:

4.b. WBS Checklist for items requested **before the Vancouver Meeting**

Checklist for WBS tasks in the construction cost estimates due by June 25, 2006:

- Preparing bid packages, vendor liaison costs
- Developing multiple vendors
- Non-recurring industrial setup and tooling
- Purchase of test quantities and QC
- Manufacturing and QC
- Production test stands
- Acceptance testing and QA
- Industrial or lab space & infrastructure
- Warehouse storage, shipping containers, shipping fixtures
- System final assembly
- Stands or mounts for final installation
- Installation, tooling and fixtures
- Alignment
- Safety review & ES&H (beyond reviews of preliminary or conceptual designs)
- Systems integration, diagnostic equipment
- Software, computing equipment, test setup DAQ hardware, etc.

4.c. WBS Checklist for items requested **after** the Vancouver Meeting

Checklist for WBS tasks that are not part of the construction cost, but for which estimates are due by September 15, 2006:

- Engineering and design labor (pre-construction)
- Consultant, architect, and other external expert labor
- Design reviews
- Prototyping and R&D
- Reliability engineering
- System integration engineering
- Testing early designs and QA
- System commissioning (need estimate, but not part of construction cost)
- Management, Cost & Schedule maintenance for life of project

This is a real cost for *continued operations* of the ILC. Therefore, it is not to be included in the construction cost estimate.

Some items, such as installation or alignment for which a specific sub-group has been set up, will be assessed globally, than, as required, split into various Area Systems prorate according to their needs.

The cost of surface land and underground easements are not to be included in the cost estimates, since this is anticipated to be provided by the host country. The hectare area quantities will be listed as a separate requirement.

4.d. WBS Information to be provided

For each WBS Task provide the following information:

- **WBS Dictionary entry:** examples:
http://www-ilcdeb.fnal.gov/RDR/WBS_Dictionary_Example.pdf
- Provide a brief description. **Be as specific as you can.** What is this task? (example: Design, procure a power supply)
- What are the specifications? (example: 3000 amp, 25 V, estimated weight 2.5 tons, estimated footprint 1.5 x 1.5 m**2, height 2 m)
- What are the boundaries with respect to other tasks or systems? (Example: this supply starts at 440 VAC circuit breaker and extends to but does not include 3000 amp buss work, LCW piping and hoses are not included in this task but covered by WBS.2.2.9.2, installation and commissioning is covered by WBS 3.2.2.7)
- What does this system need from other systems? (e.g. this power supply requires 440 V 50-60 Hz AC @ 200 amps and 30 GPM of LCW @ max temp of 90 F, unit shipping weigh is approx 3 tons and will need 6 sq ft of

indoor storage from vendor delivery through installation in the tunnel, a fixture required to lift unit, this cost is in WBS 3.2.2.6)

- **Basis of estimate: Where did you get the numbers you put into the cost estimate for this task?** (Fill out DCB risk form for this task)

http://www-ilcddb.fnal.gov/RDR/Basis_of_Estimate.pdf

Provide a short, but detailed explanation paragraph of how you got the cost. (e.g. unit cost scaled from SNS Project, a 90% learning curve was applied based on a total of units of 3600 for this entry and WBS 3.4.5.3, etc.)

- **Quantity required**
- **Materials and Services Estimate for the task**
- **Internal (Institutional) Labor:**

Estimate number of person-hours labor required to accomplish this WBS task in appropriate labor categories.

Type: Specify the type of labor (Scientist, mechanical engineer, electrical engineer, designer, lead tech, junior tech, purchasing agent, etc.). For simplicity, the RDR cost estimate will only sum up three levels of internal labor: **engineers/scientists, technicians, and administrators.** However, if you break down the labor into more categories in preparing your estimate, please submit that information. It will likely be needed later in preparing the TDR.

Labor Time Profile: Estimate the number person-hours of labor per year versus time from the start time of project

- **Source:** Assumed labor source (University, lab, industrial, contract, etc.)
- **Profile space requirements (if any):** for on-site fabrication, testing, conditioning, storage/inventory, servicing, repair, etc.
- **Estimated Total Cost**

5. Cost Estimating Instructions

5.a. Project Schedule: As an initial (temporary) working hypothesis, assume a 7 year construction schedule from project approval to completion of installation of all elements and ready-to-begin overall machine commissioning. Assume 1 year (likely optimistic) at the beginning for finalizing engineering design, specifications, drawings, preparation of bids, bidding process, choice of contractors, and mobilization. Assume parallel activities of tunneling, infrastructure installation, component installation, and systems testing. This assumes adequate early funding to allow a technically limited schedule. Staged Commissioning of a given sub-system can begin as soon after installation of that sub-system, provided operating funds are available.

http://www-ilcddb.fnal.gov/RDR/construction_schedule.pdf

The Conventional Facilities and Siting group is expected to present a civil construction time schedule at Vancouver. At that time, the other Area, Technical, and Global Systems leaders will be requested to propose the schedules for their systems, compatible with the CFS construction schedule.

5.b. System Boundaries: Area System leaders work together to define boundaries to the next interconnected system or systems. Boundaries include mechanical structures, power and water, support electronics, controls interfaces, beam parameters, etc. Boundaries are used to divide technical responsibility and cost estimate responsibility.

5.c. Graded Approach: The goal is to be inclusive in the cost estimate. The starting point is to include everything to get the “value” of systems. This information will be used differently in each region. However, there must be a graded approach in producing the cost estimate due to limited engineering resources available. Thus estimators should focus on the major cost drivers within each Area System. We desire to roll-up the detail for each element in the WBS for the RDR cost estimate at the few * 0.1% of the entire ILC cost, if possible. This means we would like about 500 or so elements in the WBS that is used for cost/scope optimization. At this stage, we don’t know what the total cost will be, but as a guideline or rule of thumb, we want the total cost (=quantity*unit cost) for each lowest level WBS element submitted to the Cost Engineers to be no more than ~10 M€. If this lowest cost estimate is greater than ~10 M€, please go back and break it down further, where possible. In some cases, further breakdown might not be possible. For example, there might be 700 klystron tubes to be purchased at 0.5 M€ each, giving a total of 350 M€, but the irreducible number (lowest sensible estimate level) is still 0.5 M€ for each purchased unit. Similarly, there are lots of meters of tunnel at ~\$ 20 K per meter.

Since all systems and sub-systems are so unique, this general statement can’t be any more precise or prescriptive. Try to define and use a naturally reasonable number of WBS elements and cost per element, and not go to either a too detailed or not-detailed-enough extreme. Please ask if you have a question. Engineering effort to produce the cost estimate should be allocated accordingly. Please don’t spend an inordinate amount of time producing a very refined cost model and estimate beyond this level.

Overall, the largest cost driver is the Main Linac, especially with the multiplication by many units of Cryomodules (cavities, cryomodule assembly, couplers) and RF systems (klystrons and distribution). It is important to get the cost right for components produced in large numbers. Conventional Facilities is the next leading cost driver. The layout of the various machine elements, especially the transverse cross sections of tunnels, wider sections (caverns), and any special access areas, temperature control, cooling water requirements, etc. will be vitally important to the CF&S group in producing their part of the cost estimate. It is especially important to get early specifications and **sketches** (especially useful) from the Area System groups and to the CF&S group quickly.

5.d. Scaling from other Projects: There are many subsystems which are similar to those previously built (or estimated for TESLA, NLC, GLC, USLCTOS) where the prior actual costs can be used, scaled, or parameterized to produce unit cost, cost per unit length, etc., estimates for the ILC with minimum engineering or bottom-up estimating. Such items include conventional magnets (e.g. for Damping Rings) or even superconducting magnets (for Cryomodules or Beam Delivery System), warm FODO transfer lines, vacuum systems, mechanical supports, control system, standard

instrumentation, cryogenics plants and distribution systems, dumps, and collimators. The important parameters will then be numbers of units or lengths required.

5.e. Learning Curves: A Learning Curve is an industrial tool or formula for the expected reduction of unit costs for large quantity production of components. See the URL: http://www-ilcdecb.fnal.gov/RDR/Learning_Curves.pdf

5.f. Cost Estimates: We will quote the **50% point** for each cost estimate. By this we mean that if the procurement or bidding process is repeated many times, there would be a probability distribution for the accepted bid (lowest reasonable cost for required quality). The 50% point or median estimate is that estimate where 50% of the accepted bids are below that point and 50% are above. Although this single point is adequate for the first estimate at Vancouver, to complete the RDR we will need an estimate of the uncertainty in the 50% cost estimate for each item, or the spread in the probability distribution function for the cost estimate. Please keep this later requirement in mind while developing the initial cost estimates for Vancouver. For more details see: http://www-ilcdecb.fnal.gov/RDR/Cost_Estimates_and_Uncertainties.pdf

5.g. Include NO Contingency: In this model of an international cost estimate, contingency is explicitly excluded. The European and Asian project management methodologies assume that all the design and estimating has been done up-front, inclusively, so there will be no add-ons due to incomplete engineering or scope changes (all homework has been done at this stage) and that the estimates are statistically robust so that over-runs in one area will be compensated by under-runs in another. Projects are described as “design-to-cost” and maintaining scope and schedule are secondary compared to completing the project within budget without recourse to extra contingency funding.

Those generating cost estimates are reminded to avoid all added contingencies. The Baseline Configuration already includes installed redundant components and operating margins. However, we must **avoid** including any ***hidden contingencies*** such as:

over-designing components and systems to make sure they will never be a problem – an easy trap when reliability and “high availability” are key ingredients in delivering integrated luminosity

“I’ll make sure *my* system never fails!”

and over-estimating the cost by giving, for example, a 98% cost estimate instead of the required 50% estimate

“I’ll make sure *my* system comes in under budget!”

The RDR cost estimate will include a Risk Analysis to indicate what variations in the total cost could be anticipated and which will be able to provide both the 50% and 98% levels of the probability distribution of the cost estimate as needed.

5.h. Spares: The installed, redundant, not-activated, auxiliary components, such as cryomodules and klystrons which provide an operating and reliability margin as defined by the BCD should be included under the construction project cost estimate. An inventory of not-installed spare components, for example, sitting in a warehouse, is not considered part of the construction project. Exceptions will be made for specialized

components (e.g. cryomodules, but not klystrons) where, should one fail, it would be difficult to re-open a production facility after completion of the production run.

A proposal, based on prior operational and reliability experience with similar systems, should be made by the Area System, Technical System, and Global System leaders for the number of spares of these kinds of items that should be fabricated as part of the construction project. The Cost Engineers will have responsibility for determining how many of each type of these spares should be included in the construction cost estimate. Note that consumables, for example klystron tubes, should not be considered for spares but must be paid for under operating funds. Likewise, operating funding will be required for the (out of guarantee) repair or replacement of components that fail during the commissioning or initial operations periods (infant mortality).

5.i. The Five Horsemen (additional costs): John Cornuelle and Ray Larsen at SLAC customarily consider five additional costs to a project beyond the acquisition costs paid to a vendor to deliver an item. These include: Conceptual Design, R&D, (final) Design, Sustaining Engineering (see description below), and Install-Integrate-Test. The first three items: Conceptual Design, R&D, and (final) Design are needed before beginning acquisition, either by internal fabrication or procurement from a vendor. The last two times: Sustaining Engineering and Install-Integrate-Test occur during or after the acquisition phase.

Description: Sustaining Engineering: engineering, inspection, supervision, construction management, pre-operational maintenance performed after project funding authorization. Covers engineering activities after design and during construction, receipt of materials, supervision of pre-assembly and factory , and incoming inspection, checking conformity to specifications, and component testing.

Apart from the M&S costs associated with R&D, these Five Horsemen are typically mostly institutional (laboratory) Labor costs, but there can be some Materials & Services costs, for example travel for vendor inspection, design software, test equipment, etc.

For this ILC construction cost estimate, Conceptual Design and R&D are defined to be pre-construction and therefore not part of the cost estimate. We anticipate that much final design will have be completed after project funding authorization, so (final) Design (see “What’s Included...”, above, for more detail), Sustaining Engineering, and Install-Integrate-Test are included in the construction cost estimate.

Ray Larsen provided an old example of a fairly complete calculation (but without listing a range for the cost estimate) calculation for the NLC X-Band Modulator that may be instructive. http://www-ilcdecb.fnal.gov/RDR/NLC_X-Band_Estimate_042406.xls

5.j. Cost Sensitivities: We anticipate that the cost estimates compiled may indicate that some overall optimizations and cost reduction measures will be required. Be prepared to propose cost cuttings and savings for your system after the Vancouver meeting. Such optimization/reduction exercises will depend on having not only costs for individual sub-

systems, but also the unit costs. These unit costs will be specifically listed in the WBS for the Main Linac cryomodules and RF power distribution systems which are used in multiple Area Systems. Other desired unit cost parameters for cost sensitivity studies include: per meter costs for TBM tunnels of different diameters, per cubic-meter costs for Drill and Blast caverns and tunnels, shaft costs for different diameters, (all of these construction costs should include finishing costs for floor, lining, power distribution, lighting, HVAC, groundwater pumping, etc. These are general services which are not directly linked to the accelerator or detector, i.e. the Area and Technical system power components begin at the cables connecting to the power breakers or disconnects.), cost per volume, weight, and $\int B dL$ ($\int G dL$) for magnets, and cost per meter of simple vacuum systems (copper, aluminum, or stainless steel pipes), special vacuums for DR, BDS, and dump lines, bakeable vacuum pipes (if required) high vacuum, ultra-vacuum for storage ring, and high vacuum under out gassing conditions (e.g. severe synchrotron radiation backgrounds), etc.

5.k. Watch out for duplication: There are several areas where it will be easy to double count the cost and manpower resource requirements. If there is any ambiguity, be sure to check with the parallel group in question and the Design Cost Board. You can't beat good communications! It is preferable to include an element, noting that it might be double counted, rather than to have it not included by assuming that it was included by the other group. Some of these topics of possible duplication include installation and alignment. There is the specific Installation Global System group and alignment tasks are included under the Conventional Facilities and Siting Global System group. Those tasks that are **specific** to a given Area, Technical, or Global System, such as the fabrication in place of the laser system for the photo-injector, the technical precise positioning system for the cryomodules, and installation of the cryogenic plants and headers, should be estimated under the corresponding Area, Technical, and Global System groups. The Installation Global System group should estimate the rigging, the power tie-in from the breaker panels to the final devices, cabling from power supplies and electronic modules to their associated components, etc. The Conventional Facilities Global System is beginning to work with the CERN Large Scale Metrology Group on cost estimates for elements such as geodesy, civil engineering survey, underground networks, metrology of the technical elements, alignment of the beam lines, equipment, computing, and alignment R&D.

5.l. Transportation Costs: (preliminary instructions, still under review) The estimated cost of a component must include delivery costs to the ILC site. This includes any special shipping containers, handling fixtures, etc. in addition to the actual cost paid to a transport company. Since we do not know where the ILC will be sited, or where a particular component will be produced, an "average" shipping model is proposed that assumes that 1/3 of the components would be delivered to a site within the same region as the production facility and 1/3 to sites in each of the other two regions. That is, send 1/3 to Fermilab, 1/3 to CERN or DESY, and 1/3 to rural Japan.

5.m Optimization – Construction Costs vs. Long Term Operations (added 28july06)

The question of whether we should be designing and cost estimating for the lowest construction cost or the lowest cost over the life of the project which includes the continuing operations cost for electrical power, cryogenics, maintenance, personnel, etc. is discussed in

http://www-ilcdeb.fnal.gov/RDR/ILC_Cost_Optimizations_21june06.pdf

The end (for now!)